**Role of Phosphorous fertilizers and P solubilizes on growth,yield and economics of different cultivars of Grain amaranth (*Amaranthus hypochodriacus)*under Eastern Dry Zone of Karnataka**


## Abstract

The field experiment was carried out for two years during *Kharif* season 2018 and 2019 at Main Research Station (MRS), Hebbal, University of Agricultural Sciences, Bangalore. The pooled data of two years indicated that among the varieties, grain yield was significantly higher with Suvarna (1839 kg $ha^{-1}$) as compared to KBGA-4 (1671 kg $ha^{-1}$). Among P levels, significantly higher grain yield was recorded with application 30 kg $P_2O_5ha^{-1}$ + PSB @ 2.5 kg $ha^{-1}$ + VAM @ 2.5 $kg^{-1}$ha soil application + RD of NK&S (848 kg $ha^{-1}$) which was on par with RDF (2091 Kg $ha^{-1}$) and 20 kg $P_2O_5ha^{-1}$ + PSB @ 2.5 kg $ha^{-1}$ + VAM @ 2.5 kg $ha^{-1}$ soil application +RD of NK&S (1894 kg $ha^{-1}$). However, significantly higher yield advantage and agronomic efficiency of P were recorded with application 20 kg $P_2O_5ha^{-1}$ + PSB @ 2.5 kg $ha^{-1}$ + VAM @ 2.5 kg $ha^{-1}$ soil application + RD of NK&S (848 kg and 28.26, respectively) which was on par with 30 kg $P_2O_5ha^{-1}$ + PSB @ 2.5 kg/ha + VAM @ 2.5 $kgha^{-1}$ soil application (522kg and 26.12, respectively) and Recommended dose of fertilizer (NPKS).Similarly, plant height and panicle length was followed the same trend. Significantly higher gross returns, net returns and B:C ratio were recorded with application of 30 kg $P_2O_5ha^{-1}$+ PSB @ 2.5 kg $ha^{-1}$ + VAM @ 2.5 kg $ha^{-1}$ soil application + RD of NK&S (Rs. 110970 $ha^{-1}$, Rs.85381 $ha^{-1}$ and 4.34, respectively) which was on par with RDF (NPKS) and 20 kg $P_2O_5ha^{-1}$ + PSB @ 2.5 kg $ha^{-1}$ + VAM @ 2.5 kg $ha^{-1}$soil application as compared to other treatments.



Key words: Economics,Grain amaranth, Growth, ~~yield,~~Phosphorous use efficiency, Yield~~Economics~~


## 1. Introduction

Grain amaranth (*Amranthushypochodriacus*) is one of the pseudocereal which is highly nutritious especially in terms of protein and minerals when compared to other cereals and millets. ~~This~~ Itis considered as drought tolerant and ~~,~~ climate resilient crop because of its variable climatic ~~adoptability~~adaptability. Amaranth is a tropical annual herbaceous crop belongs to the family Amaranthaceae.It plays a predominant role in nutrition as a cheapest source of minerals

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and vitamins. The leaves and stem of amaranth are rich in protein, fat, calcium, phosphorous, β-carotene, riboflavin, niacin, sodium, iron and ascorbic acid;. where,Calciumcalcium, iron and phosphorus are the most important elements among the minerals present in amaranth (FAO, 2000). Though the exact area and production is lacking in grain amaranth, it isAmaranth is cultivated as a minor crop in several countries like Mexico, Guatemala, Peru, Bolivia, Ecuador, Argentina, Sierra Leone, Nigeria, Zambia, Kenya, Egypt, Afghanistan, Persia, China, Manchuria, Nepal and Bhutan. In India,it is widely distributed and cultivated in seventeen statesviz., Jammu and Kashmir, Himachal Pradesh, Uttaranchal, North Bihar, Sikkim, Assam, Meghalaya, Arunachal Pradesh, Nagaland, Tripura, Gujarat, Madhya Pradesh, Maharastra, Karnataka, Kerala, Tamil Nadu and Orissa.

Phosphorus is one of the major essential macronutrients for the biological growth and development of plants. Soils generally contain substantial reserves of total P, though a major part of it remains relatively inert. Lless than only 10% of the total soil P is actually utilized and enters the plant-animal cycle. Actually Indian soils are rich in P but more than two thirds of the native phosphates are in a chemical form which cannot be absorbed by plants (Thiyageshwari and Selvi 2006). Furthermore, applied P fertilizers are rendered unavailable due to its chemical fixation in the soil (Vassilev and Vassileva 2003).Amaranth crop is good in phosphorous uptake and voracious feeder of nutrients which are essential for crop plants. However, it has high P requirement and therefore responds to P application (Gupta and Thimba, 1992). Its productivity can be improved at reduced cost through combined use of Psolubilizersviz.,Phosphorous Solubilizing Bacteria (PSB) and Vesicular Arbuscular Mycorrhiza (VAM)which plays an important role in making P available to crop plants and thereby increase the yield of crop plants..

While varietal differences in efficiency of P uptake from soil has been studied for all crops but these studies are lacking in grain amaranth. Such information would be useful for identification, selection and subsequent development of breeding programmesprogramsgenotypes with high capabilities for using P in low-P soils. Combined use of P fertilizers and P solubilizers may helpshelp in efficient use of phosphorous in soil as well as reduction in application P fertilizer which can reduce cost of cultivationas these fertilizers are very costly. In this context, an experiment has been planned conductedin Grain amaranth with different P levels along with P solubilizers in grain amaranth genotypesalong with different genotypes.

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## 2. Material and methods

The experiment was carried out for two years during *Kharif* 2018 and 2019 at Main Research Station (MRS), Hebbal, University of Agricultural Sciences, Bangalore. ~~to study the effect of P fertilizer levels along with P solubilizers in grain amaranth genotypes.~~ The soil of the experimental field was sandy loam in texture and low in organic carbon (0.36%), available nitrogen (254.41 kg/ha), medium in available $P_2O_5$ (28.32 kg/ha) and available $K_2O$ (186.04 kg/ha). Soil is red sandy loam in texture withslightly acidic pH of 6.28along with normal electrical conductivity (0.25 dS/m). The experiment was laid in split plot design with two genotypes in main plots, viz., $V_1$- Suvarna, $V_2$- KBGA-4 and seven fertilizer levels in subplots, viz., $T_1$- Control, $T_2$- 20 kg $P_2O_5$/ha $T_3$- 30 kg $P_2O_5$/ha $T_4$- 20 kg $P_2O_5$/ha + PSB @ 2.5 kg/ha + VAM @ 2.5 kg/ha soil application +RD of NK&S, $T_5$- 30 kg $P_2O_5$/ha + PSB @ 2.5 kg/ha + VAM @ 2.5 kg/ha soil application, $T_6$- PSB @ 2.5 kg/ha + VAM @ 2.5 kg/ha soil application alone and $T_7$- ~~Recommended~~ recommended dose of fertilizer (NPKS), ~~. Recommended dose of fertilizer (RDF) applied~~ @ 60:40:40 NPK kg/ha. Recommended NK~~&~~ and S is common for all treatments except $T_7$. Totally there were 14 treatment combinations which were replicated thrice. The source of NPK used were urea, DAP and MOP. About 50% of nitrogen and 100% of phosphorus and potassium were applied at the time of sowing. Remaining 50% of nitrogen was top dressed after hand weeding and at the time of intercultivation at 30 DAS. PSB and VAM ~~was procured from Department of Microbiology, College of Agriculture GKVK, Bangalore and~~were applied as per the treatments. Necessary plant protection measures were taken during the infestation of sucking pests and defoliates, while no disease was found during the study period. Protective irrigation was given when there was moisture stress due to deficit of rainfall. The growth and yield parameters were recorded at the time of harvesting. Statistical analysis was done as per the formula given by Gomez and Gomez (1966).write the name of the software used for analysis.

## 3. Results and discussion

### 3.1. Growth parameters of grain amaranth as influenced by P fertilizer levels along with P solubilizes

The growth and development of the grain amaranth varieties were influenced by P levels and use of P solubilizers. The mean data of two years indicated that, the plant height,panicle length and

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number of leaves per plant (150.56 cm) was significantly higher in Suvarna variety as compared to KBGA-4 (137.29 cm). Whereas, panicle length and number of leaves per plant were significantly higher in KBGA-4 variety (59.76 cm and 116.85, respectively) as compared to Suvarna (43.15 cm and 103.92, respectively). This could be due to varietal character in which a KBGA-4 bears more small leaves than Suvarna which bears larger broad leaves and shape of the panicle and width of the leaves in each variety may differs. Decreased ~~growth~~ and increased growth among varieties observed in this study corroborate with the findings ~~described by~~of Sanginga*et al.* (2000) and Joshi*et al.* (2021)~~as earlier highlighted~~describing that hormonal, physiological and other genetic factors are responsible for growth differences.Among subplots, application of phosphorous @ 30 kg/ha along with PSB and VAM was ~~recorded~~ resulted inhigher plant height (152.17 cm) which was on par with RDF (150.50 cm) and application of phosphorous @ 20 kg/ha along with PSB and VAM (147.20 cm) as compared to other P levels.

This could be dueto the fact that phosphorus ~~which~~ encourages formationof new cells, promotes~~.~~fibrous root growth ~~(particularly the development of fibrous roots) and thereby.~~facilitating more nutrient absorption by the plant~~in turn~~ increasinges the plant growth. Similar ~~increase in growth parametersresults under higher levelsof phosphorus application~~were~~observed~~ reportedby Chakravarty and Gogoi (1991) and Jayshree *et al.* (1996). This could also be due to higher availability of nutrients which has accelerated the synthesis of chlorophyll and amino acids which are associated with photosynthetic process of plants ~~which~~ result~~ed~~ing in higher growth and development. The ~~above~~ presentresults were in line with the findings of Naveen and Mevada (2012) and Dongre (2011).

### 3.2. Yield and yield parameters of grain amaranth as influenced by P fertilizer levels along with P solubilizes

The pooled data of two years indicated that among the varieties, grain yield and stover yield was significantly higher with Suvarna (1839 and 2064 kg/ha, respectively) as compared to KBGA-4 (1671 and 1819 kg/ha, respectively). Among the subplots, significantly higher grain yield was recorded ~~with~~ from theapplication of 30 kg $P_2O_5$/ha + PSB @ 2.5 kg/ha + VAM @ 2.5 kg/ha soil application + RD of NK&S (848 kg kg/ha) which was on par with ~~Recommended~~ recommended dose of fertilizer (NPKS) (2091 g/ha) and 20 kg $P_2O_5$/ha + PSB @ 2.5 kg/ha + VAM @ 2.5 kg/ha soil application +RD of NK&S (1894 kg/ha). However, yield advantage over control and agronomic efficiency of P did not differ significantly due to the

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varieties but differed significantly with phosphorous levels. Significantly higher yield advantage and agronomic efficiency of P were recorded with the application of 30 kg $P_2O_5$/ha + PSB @ 2.5 kg/ha + VAM @ 2.5 kg/ha soil application + RD of NK&S (848 kg and 28.26, respectively) which was on par with 20 kg $P_2O_5$/ha + PSB @ 2.5 kg/ha + VAM @ 2.5 kg/ha soil application +RD of NK&S (522kg and 26.12, respectively) and ~~Recommended~~ recommended dose of fertilizer (NPKS) (522kg and 26.12, respectively).Similarly, plant height and panicle length was followed the same trend. However, 10 ml seed weight did not differ significantly (Table 2).This might be dueto better growth ~~and yield parameters~~ and better availability of nutrients at ~~crop~~ thegrowth period due to better root ~~growth~~ developmentwhich helped in more absorption of moisture and nutrients ~~was~~ asobserved by Anil Kumar *et al.* (2010) and Ojo *et al.* (2010).

The increase in stover yield at higher level of phosphorus might be due to the significant increase in growth attributes. Similar findings were revealed by Tiwari and Mishra (1997).~~The results obtained might also be due to beneficial response of the crop due to bio fertilizers.~~ Bio-fertilizers colonize the rhizosphere of the plant and promote growth by increasing the supply and/or availability of primary nutrients to the host plants. Vesicular *ArbuscularMycorrhiza* is known to enhance the uptake and transport of mineral nutrients from the soil directly into host plant roots. The ~~Similar~~ results from the present study were ~~reported b~~in agreement with~~y~~ Sandeep *et al.* (2014).

### 3.3.Effect of P fertilizer levels along with P solubilizers on economics of grain amaranth

Economics was did not found significant with the varieties.Whereas, significantly higher gross returns, net returns and B:C ratio were recorded with application of 30 kg $P_2O_5$/ha + PSB @ 2.5 kg/ha + VAM @ 2.5 kg/ha soil application + RD of NK&S (Rs. 110970/ha, Rs.85381/ha and 4.34, respectively) which was on par ~~with which was on par~~ with rRecommended dose of fertilizer (NPKS) and 20 kg $P_2O_5$/ha + PSB @ 2.5 kg/ha + VAM @ 2.5 kg/ha soil application +RD of NK&S as compared to other treatments (Table 4).The higher economic advantage could be due to the fact that higher market value for grain amaranth~~which ultimately led to higher economic returns~~. Similar findings were also reported by Ramachandra and Thimmaraju (1983) and Singh *et al.* (1985).

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## 4. Conclusion

The ~~results~~ findingsof the two years ~~findings~~ study indicated that application of 30 kg $P_2O_5$/ha + PSB @ 2.5 kg/ha + VAM @ 2.5 kg/ha soil application + RD of NK&S has evidenced in higher growth and yield which was on par with 20 kg $P_2O_5$/ha + PSB @ 2.5 kg/ha + VAM @ 2.5 kg/ha soil application + RD of NK&S. This shows that 50% ~~per cent~~ phosphorous can be reduced when we apply P solubilizing bacteria along with P fertilizers under *Alfisols* of Eastern Dry Zone of Karnataka.

## 5. References


AnilKumar,S.,Chidandappa,H.M.&VijayShankarBabu,M. (2010). Effectofdifferentsourcesofzincongrowth,yieldanduptakeofnutrientbymaizecrop(*Zea mays* L.).*MysoreJ. Agric. Sci.,*44(1): 92-99.

Chakravarty,A.&Gogoi,H.N. (1991).Effectofsource,levelandtimeofapplicationofphosphorusonirrigatedwheat.*Indian.J. Agron*.36:256-257**.**

Dongre,S.B.(201).Responseofamaranth(*Amaranthushypochondriacus*L.)toleavesof nitrogen and organic manures under south Gujarat condition. M.Sc. (Agri.)Thesis,Univ. Agric. Sci.,Navsari.

Fao(2000).Humanvitaminandmineralrequirements.www.fao.org.

Gomez,K.A.&Gomez,A.A. (1984).StatisticalProceduresforAgric.Res.2ndEd. JohnWiley&Sons,NewYork.

Gupta,V.K.andThimba,D. (1992).Grainamaranth:Apromisingcropformarginalareasof Kenya.*Food Reviews International*,8(1),51-69.

JayashreeBhaskar,Bharad,G.M.&Patil,S.N.,1996.Effectofplantpopulation,nitrogenandphosphorus ongrainamaranth.*IndianJ.Agron.,*41(1):181-182.

Joshi, G.H., Thalkar, M.G., Lanje, S.N., PagoreG.K. & KadamA.D. (2021).Effect of PSB, VAM and phosphorus levels on plant height, shoot and root growth in chickpea (Cicer arietinum L.).The Pharma Innovation Journal, 10(4): 550-553.

Naveen, K.H. &Mevada, K.D. (2012). Performance of different composts and biofertilizer on yield and quality of green gram (Vigna radiata L.), Adv. Res. J. Crop Improv., 3 (1): 17- 20.

Ojo,O.D.,Akinrinde,E.A.&Akoroda,M.O.(2010).Residualeffectsof phosphorussourcesingrainamaranthproduction. *J.PlantNutrn.*,**33**(5):770-783.

Parashurama,P.,Duraisamy&Mani,M.K. ( 2000).Effectoforganic,inorganic and bio-fertilizers on soil fertility under double cropping system inrainfedred soils. *Indian J.Agron.*, 45 (2):

242-247.

Ramachandra, H. A.&Thimmaraju. K. R. (1983). Effect of different levelsofN&PongrowthcomponentsandYieldofAmaranthusCVA-25.*MysoreJ.AgriSci.*,**17** (2): 158 -164.

SangingaN., O. Lyasse&Singh, B. B. (2010).Phosphorus use efficiency and nitrogen balance of cowpea breeding lines in a low P soil of the derived savanna zone in West Africa. *Plant and Soil*, 220: 119–128.

SandeepKumar,Ripudaman,S.,Saquib,M.,Dharmendra,S.&Awadhesh,K.(2014).Effectofdifferent combinationsofvermicompost,biofertilizers and chemical fertilizers on growth, productivity and profitability inchickpea.*Plant Archives*,14(1): 267-270**.**

Singh,U.C.,Sundararajan,S.&Veeraragavathatham,D. (1985).Effectofsplitapplicationnitrogenongrowthandyieldofamaranthus(*Amaranthust ristis*L.)CO.3. *SouthIndian Horti.*,33(2):100-102.

Thiyageshwari, S. &Selvi, D. (2006). Soil enzyme activity as affected by theintegrated use of p sources with vermicompost and phosphobacteria in cotton(*Gossypium Hirsutum*) pulse (*Vigna ungigulata*) mix in an inceptisol.The 18thWorldCongress ofSoil Science,July 9-15,USA,Pp. 163-164.

Vassilev, N. &Vassileva, M. (2003). Biotechnological solubilization of rockphosphateonmediacontainingagro-industrialwastes.*AppliedMicrobio.Biotech.*,61(6):435-40.

**Table 1. Growth parameters of Grain amaranth as influenced by levels of phosphorous fertilizer and bio fertilizers.**

| Treatment details | Plant height (cm) | | | Panicle length (cm) | | | No. of leaves per plant at harvest | | |
|---|---|---|---|---|---|---|---|---|---|
| **Mail Plot (Varieties)** | **2018** | **2019** | **Mean** | **2018** | **2019** | **Mean** | **2018** | **2019** | **Mean** |
| $V_1$-Suvarna | 174.30 | 106.81 | **140.56** | 45.53 | 40.76 | **43.15** | 15.16 | 12.68 | **13.92** |
| $V_2$- KBGA-4 | 162.19 | 112.38 | **137.29** | 62.89 | 56.64 | **59.76** | 25.45 | 21.26 | **23.36** |
| **S.Em±** | 2.19 | 2.14 | 1.77 | 2.72 | 3.10 | 0.78 | 0.86 | 1.05 | **0.96** |
| **CD @5%** | **9.44** | **9.21** | **7.61** | **11.71** | **13.33** | **3.35** | **2.25** | **3.20** | **2.73** |
| **Subplots (P levels )** | | | | | | | | | |
| **$S_1$** | 148.33 | 95.00 | **121.67** | 43.67 | 38.67 | **41.17** | 10.14 | 8.25 | **9.20** |
| **$S_2$** | 160.00 | 100.00 | **130.00** | 49.83 | 44.83 | **47.33** | 13.25 | 10.45 | **11.85** |
| **$S_3$** | 170.00 | 109.67 | **139.83** | 54.37 | 50.67 | **52.52** | 15.45 | 12.48 | **13.97** |
| **$S_4$** | 178.57 | 115.83 | **147.20** | 58.67 | 53.33 | **56.00** | 17.35 | 15.26 | **16.31** |
| **$S_5$** | 185.17 | 119.17 | **152.17** | 62.90 | 56.07 | **59.48** | 18.16 | 16.24 | **17.20** |
| **$S_6$** | 154.67 | 107.50 | **131.08** | 50.00 | 45.00 | **47.50** | 12.14 | 9.25 | **10.70** |
| **$S_7$** | 181.00 | 120.00 | **150.50** | 60.03 | 52.33 | **56.18** | 17.85 | 14.65 | **16.25** |
| **S.Em±** | **2.76** | **2.94** | **1.62** | **1.65** | **2.01** | **1.62** | **0.32** | **0.65** | **0.49** |
| **CD @%** | **8.06** | **8.59** | **4.72** | **4.82** | **5.87** | **4.72** | **1.05** | **1.85** | **1.45** |
| **Interactions (MxS)** | | | | | | | | | |
| **S.Em±** | **3.93** | **4.16** | **2.49** | **2.38** | **2.19** | **2.29** | **2.13** | **2.56** | **2.45** |
| **CD @5%** | **NS** | **NS** | **NS** | **NS** | **NS** | **NS** | **NS** | **NS** | **NS** |

NOTE : S1- Control (Recommended dose of NK&S) S2- 20 kg $P_2O_5$/ha + Recommended dose of NK&S
S3- 30 kg $P_2O_5$/ha + Recommended dose of NK&S S4- 20 kg $P_2O_5$/ha + PSB @ 2.5 kg/ha + VAM @ 2.5 kg/ha soil application +RD of NK&S S5- 30 kg $P_2O_5$/ha + PSB @ 2.5 kg/ha + VAM @ 2.5 kg/ha soil application + RD of NK&S
S6- PSB @ 2.5 kg/ha + VAM @ 2.5 kg/ha soil application alone + RD of NK&S, S7. Recommended dose of fertilizer (NPKS)

**Table 2.Yield and yield parameters of Grain amaranth as influenced by levels of phosphorous fertilizer and P solubilizers.**

| Treatment details | Grain yield (kg/ha) | | | Fresh stover yield (t/ha) | | | 10 ml seed weight | | |
|---|---|---|---|---|---|---|---|---|---|
| **Mail Plot (Varieties)** | **2018** | **2019** | **Mean** | **2018** | **2019** | **Mean** | **2018** | **2019** | **Mean** |
| $V_1$-Suvarna | 1837 | 1513 | **1675** | 2336 | 2018 | **2177** | 9.02 | 8.48 | **8.75** |
| $V_2$- KBGA-4 | 1671 | 1332 | **1502** | 2175 | 1836 | **2005** | 9.00 | 8.71 | **8.86** |
| **S.Em±** | **27** | **25** | **19** | **38** | **42** | **40** | **0.23** | **0.29** | **0.24** |
| **CD @5%** | **114** | **107** | **82** | **125** | **132** | **128** | **0.98** | **1.25** | **1.05** |
| **Subplots (P levels )** | | | | | | | | | |
| **$S_1$** | 1372 | 1001 | **1186** | 1870 | 1552 | **1711** | 8.92 | 8.33 | **8.63** |
| **$S_2$** | 1501 | 1196 | **1349** | 2061 | 1694 | **1877** | 9.00 | 8.33 | **8.67** |
| **$S_3$** | 1675 | 1396 | **1535** | 2176 | 1891 | **2033** | 9.00 | 8.67 | **8.83** |
| **$S_4$** | 1894 | 1635 | **1764** | 2398 | 2130 | **2264** | 9.00 | 8.67 | **8.83** |
| **$S_5$** | 2019 | 1759 | **1889** | 2520 | 2252 | **2386** | 9.50 | 9.17 | **9.33** |
| **$S_6$** | 1533 | 1267 | **1400** | 2032 | 1756 | **1894** | 9.00 | 8.67 | **8.83** |
| **$S_7$** | 2004 | 1709 | **1856** | 2540 | 2230 | **2385** | 8.67 | 8.33 | **8.50** |
| **S.Em±** | **58** | **24** | **30** | **58** | **44** | **51** | **0.20** | **0.16** | **0.15** |
| **CD @%** | **171** | **70** | **86** | **171** | **135** | **153** | **0.59** | **0.46** | **0.43** |
| **Interactions (MXS)** | | | | | | | | | |
| **S.Em±** | **80.62** | **35.10** | **40.89** | **85.62** | **38.10** | **61.86** | **0.31** | **0.29** | **0.26** |
| **CD @5%** | **NS** | **NS** | **NS** | **NS** | **NS** | **NS** | **NS** | **NS** | **NS** |

NOTE : S1- Control (Recommended dose of NK&S) S2- 20 kg $P_2O_5$/ha + Recommended dose of NK&S
S3- 30 kg $P_2O_5$/ha + Recommended dose of NK&S S4- 20 kg $P_2O_5$/ha + PSB @ 2.5 kg/ha + VAM @ 2.5 kg/ha soil application +RD of NK&S S5- 30 kg $P_2O_5$/ha + PSB @ 2.5 kg/ha + VAM @ 2.5 kg/ha soil application + RD of NK&S
S6- PSB @ 2.5 kg/ha + VAM @ 2.5 kg/ha soil application alone + RD of NK&S, S7. Recommended dose of fertilizer (NPKS)

**Table 3. Yield advantage and agronomic efficiency of Grain amaranth as influenced by levels of phosphorous fertilizer and bio fertilizers.**

| Treatment details | Yield advantage over control (kg) | | | Agronomic efficiency of P (Kg grains kg$^{-1}$ P) | | |
|---|---|---|---|---|---|---|
| **Mail Plot (Varieties)** | **2018** | **2019** | **Mean** | **2018** | **2019** | **Mean** |
| $V_1$-Suvarna | 460 | 473 | 466 | 14.68 | 15.58 | 15.13 |
| $V_2$- KBGA-4 | 307 | 372 | 339 | 10.74 | 12.30 | 11.52 |
| S.Em ± | **286** | **17** | **112** | **5.94** | **0.58** | **3.25** |
| **CD @5%** | **NS** | **NS** | **NS** | **NS** | **NS** | **NS** |
| **Subplots (P levels )** | | | | | | |
| **$S_1$** | 0 | 0 | 0 | 0 | 0 | 0 |
| **$S_2$** | 130 | 195 | 162 | 6.49 | 9.75 | 8.12 |
| **$S_3$** | 303 | 395 | 349 | 10.12 | 13.16 | 11.64 |
| **$S_4$** | 522 | 634 | 578 | 26.12 | 31.69 | 28.90 |
| **$S_5$** | 848 | 758 | 803 | 28.26 | 25.26 | 26.76 |
| **$S_6$** | 161 | 266 | 213 | 0.00 | 0.00 | 0.00 |
| **$S_7$** | 719 | 708 | 714 | 17.98 | 17.70 | 17.84 |
| S.Em ± | **136** | **24** | **69** | **3.61** | **4.81** | **4.65** |
| **CD @%** | **397** | **70** | **202** | **10.53** | **15.58** | **15.13** |
| **Interactions (MXS)** | | | | | | |
| S.Em ± | **32.15** | **33.84** | **120.0** | **6.32** | **3.41** | **2.34** |
| **CD @5%** | **NS** | **NS** | **NS** | **NS** | **NS** | **NS** |

Note: AE= (GYf-GYc)/PsWhere, GYf- grain yield of fertilized plot, GYc- grain yield of control plot, Ps- Quantity of P fertilizer applied

NOTE : S1- Control (Recommended dose of NK&S) S2- 20 kg $P_2O_5$/ha + Recommended dose of NK&S

S3- 30 kg $P_2O_5$/ha + Recommended dose of NK&S S4- 20 kg $P_2O_5$/ha + PSB @ 2.5 kg/ha + VAM @ 2.5 kg/ha soil application +RD of NK&S S5- 30 kg $P_2O_5$/ha + PSB @ 2.5 kg/ha + VAM @ 2.5 kg/ha soil application + RD of NK&S
S6- PSB @ 2.5 kg/ha + VAM @ 2.5 kg/ha soil application alone + RD of NK&S, S7. Recommended dose of fertilizer (NPKS)

**Table 4. Economics of Grain amaranth as influenced by levels of phosphorous fertilizer and bio fertilizers.**

| Treatment details | Cost of cultivation (Rs./ha) | | | Net returns (Rs./ha) | | | B:C ratio | | |
|---|---|---|---|---|---|---|---|---|---|
| **Mail Plot (Varieties)** | **2018** | **2019** | **Mean** | **2018** | **2019** | **Mean** | **2018** | **2019** | **Mean** |
| $V_1$-Suvarna | 27834 | 28834 | 28334 | 61080 | 46835 | 53958 | 2.23 | 1.62 | 1.92 |
| $V_2$- KBGA-4 | 27834 | 28834 | 28334 | 54159 | 37789 | 45974 | 1.98 | 1.31 | 1.64 |
| **SE.m** | **-** | **-** | **-** | **1481** | **1244** | **838** | **0.05** | **0.04** | **0.03** |
| **CD @5%** | **-** | **-** | **-** | **6373** | **5354** | **3604** | **0.23** | **0.18** | **0.12** |
| **Subplots (P levels )** | | | | | | | | | |
| **$S_1$** | 26589 | 27589 | 27089 | 40992 | 22444 | 31718 | 1.58 | 0.81 | 1.20 |
| **$S_2$** | 27864 | 28864 | 28364 | 46211 | 30919 | 38565 | 1.69 | 1.07 | 1.38 |
| **$S_3$** | 28589 | 29589 | 29089 | 54162 | 40186 | 47174 | 1.93 | 1.36 | 1.64 |
| **$S_4$** | 28364 | 29364 | 28864 | 65335 | 52361 | 58848 | 2.34 | 1.78 | 2.06 |
| **$S_5$** | 29589 | 30152 | 29870 | 72644 | 60336 | 66490 | 2.84 | 2.19 | 2.52 |
| **$S_6$** | 26986 | 27986 | 27486 | 48639 | 35352 | 41996 | 1.84 | 1.26 | 1.55 |
| **$S_7$** | 29856 | 30856 | 30356 | 73352 | 54586 | 63969 | 2.49 | 1.77 | 2.13 |
| **SE.m** | **-** | **-** | **-** | **2598** | **1204** | **1357** | **0.09** | **0.04** | **0.05** |
| **CD @%** | **-** | **-** | **-** | **7583** | **3513** | **3960** | **0.27** | **0.12** | **0.14** |
| **Interactions (MXS)** | | | | | | | | | |
| **SE.m** | **-** | **-** | **-** | **9735** | **1804** | **5057** | **0.20** | **0.15** | **0.17** |
| **CD @5%** | **-** | **-** | **-** | **NS** | **NS** | **NS** | **NS** | **NS** | **NS** |

NOTE : S1- Control (Recommended dose of NK&S) S2- 20 kg $P_2O_5$/ha + Recommended dose of NK&S
S3- 30 kg $P_2O_5$/ha + Recommended dose of NK&S S4- 20 kg $P_2O_5$/ha + PSB @ 2.5 kg/ha + VAM @ 2.5 kg/ha soil application +RD of NK&S S5- 30 kg $P_2O_5$/ha + PSB @ 2.5 kg/ha + VAM @ 2.5 kg/ha soil application + RD of NK&S
S6- PSB @ 2.5 kg/ha + VAM @ 2.5 kg/ha soil application alone + RD of NK&S, S7. Recommended dose of fertilizer (NPKS)